Three Surprising Applications: Don't be myth-LED

Fred Davis
Fred Davis Corporation
Energy-Efficient Lighting Wholesalers
Since 1983

NESEA
BuildingEnergy 2014
WTC, Boston
March, 2014

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Three Surprising Applications: Don't be myth-LED

Learning Objectives:

After attending this session, participants will...

1. Learn why LEDs might achieve superior energy conservation.

2. Separate hype from reality in the marketplace with concrete examples.

3. Encourage the use of reputable third-party resources in lighting technology.

LEDs: Resources

ENERGY STAR® Program Requirements
Product Specification for Lamps (Light Bulbs)

Eligibility Criteria
Version 1.0

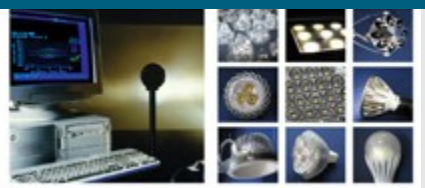
ENERGY STAR® Program Requirements
for Luminaires

Partner Commitments

Illuminating Engineering Society

U.S. Department of Energy | Energy Efficiency & Renewable Energy

CALiPER Program



Municipal Solid-State Street Lighting Consortium

Commercially Available LED Product Evaluation and Reporting

LEDs: Resources

CALiPER

Mia Paget

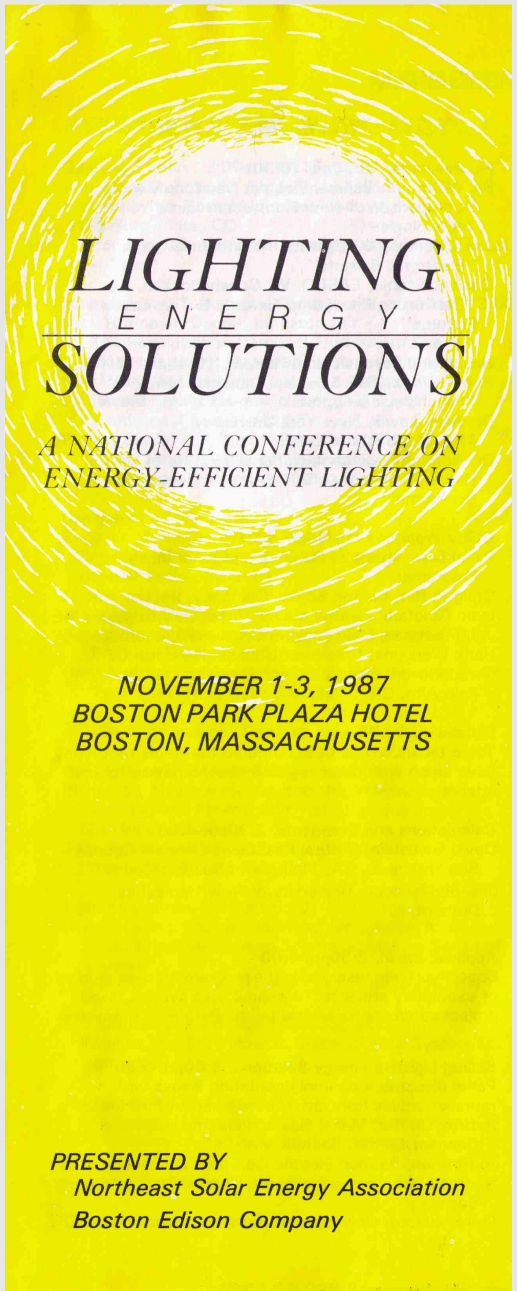
Biography

Mia Paget is currently managing the DOE's Solid State Lighting Commercial Product Testing Program to provide guidance and support to the DOE SSL commercialization efforts and to provide objective product performance information to the public. Mia also applies her expertise toward the research and development of new solutions for the current and future energy

Salute to a brilliant and intrepid explorer.

Large Changes in Lighting 25 Years Ago

Some of the names	Some of the topics
Amory Lovins	CFLs
Rudy Verderber	
John Fetters	Daylighting
Jim Grady	
Harvey Bryan	Controls
Ellyn Eder	
Karl Gee	Electronic Ballasts
David Goldstein	
Dennis Mallett	Utility Programs
Lynn Goldfarb	
Steve Nadel	Standards
Glenn Reed	
Robert Sardinsky	
Alex Wilson	NOT LEDs!
George Wood	

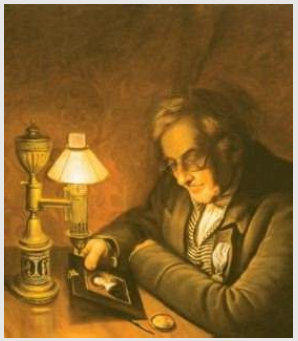


Large Changes in Lighting 19th C.

← candle

= 0.16 lumens per watt

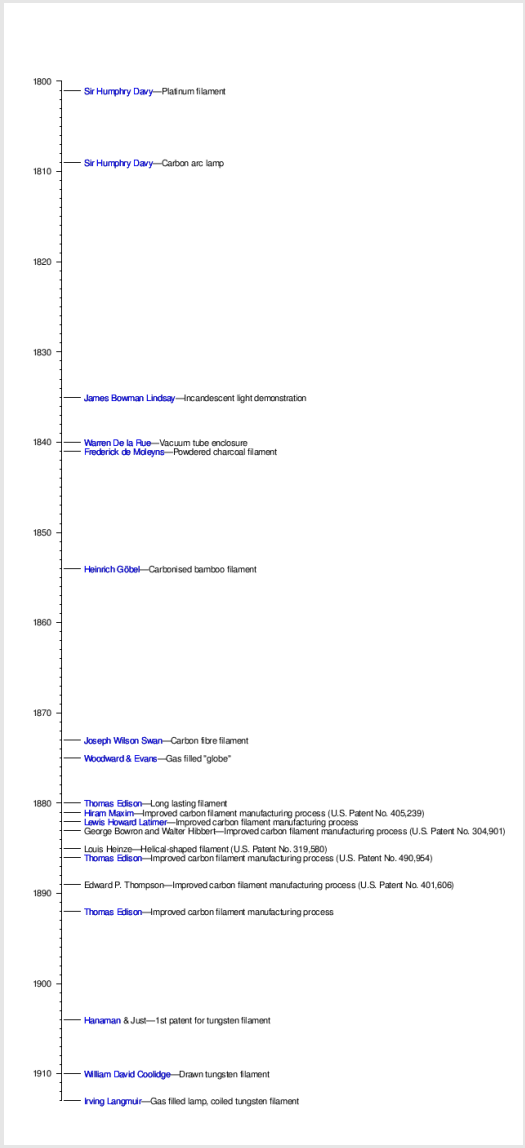
1820: whale oil →



← 1850 kerosene (coal distillate)

1860 gas (coal gas) →

Large Changes in Lighting 19th C.



← 1802-1913: Timeline of the early evolution of the incandescent light bulb

1879 →
Edison's carbon-filament incandescent lamp

1882 **1.5 LPW**

Genius is one percent inspiration, ninety-nine percent perspiration.

– Thomas Alva Edison, 1923

Large Changes in Lighting 19th C.

1889

The Starry Night

It often seems to me that the night is much more alive and richly colored than the day.

Vincent van Gogh

Large Changes in Lighting 20th C.

1905 carbon filament: 4 LPW

1911 tungsten filament: 12 LPW a 3x gain →

1940 first fluorescent

1961 first L.E.D. (indicator)

1970 first high-pressure sodium

1980 first screw-based compact fluorescent

Edison Tech Center

What's Wrong with Retro?

Retro.

Energy-Awful!!

Ask why.

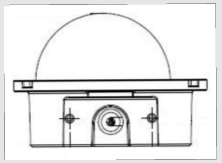
Large Changes in Lighting 21st C.

←2009 over half of vendors *SUDDENLY* "*have*" LED products

2011→ nothing but LEDs!

Large Changes in Lighting 21st C.

Light Emitting Diode: a semiconductor device,
as are computer chip and PV cell.



LEDs have moved from indication … to illumination.

A new, fast-moving, dynamic field.

Vast explosion is < five years old; the emergence of significant energy-advantageous models in more than one niche is probably more like one or two years.

LEDs are catching old technologies ... but niche by niche.

A chaotic minefield! … Don't be myth-LED!

Large Changes in Lighting 21st C.

Big problems finding good quality LED products

Fred says:

"Of all LED products (bulbs, fixtures) available,
Perhaps ~~90%~~ ~~70%~~ 50% of them are not worth purchasing."

!

Are LEDs Energy-Advantageous?

Are LEDs Energy-Advantageous?

Correct!

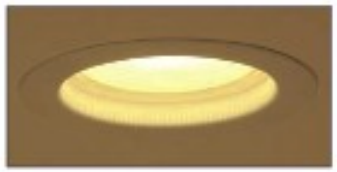
The surprising status of the energy-worthiness of LEDs in three lighting applications

Are LEDs Energy-Advantageous?

Different Applications:

- A-Lamps (general-purpose bulbs)

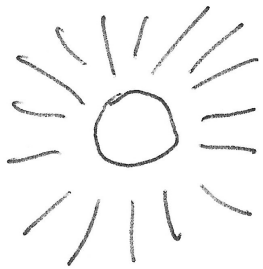
- (Recessed Can Fixtures)



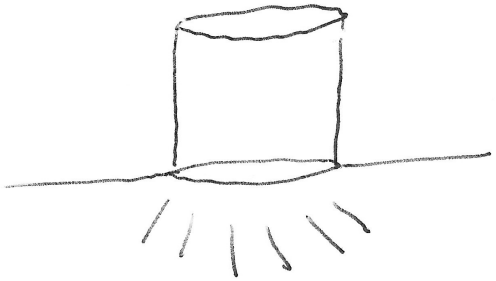
- Indoor Residential Fixtures

- Streetlights

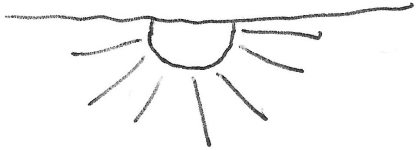
Are LEDs Energy-Advantageous?



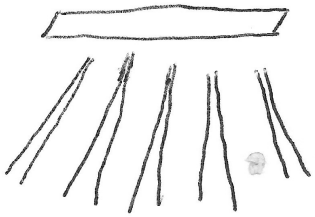
spherical



conical

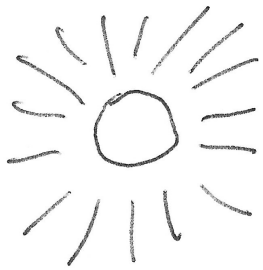


hemi-spherical

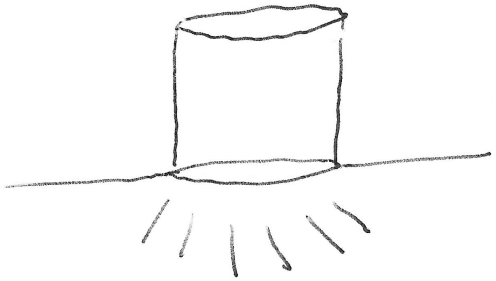


many directed beams

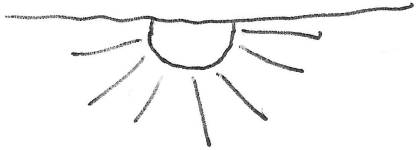
Are LEDs Energy-Advantageous?



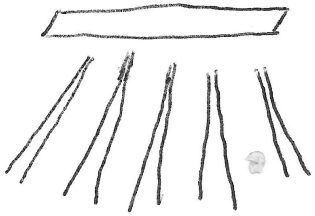
A-Lamps:
omni-directional



Recessed Can Fixtures:
only directional light is needed

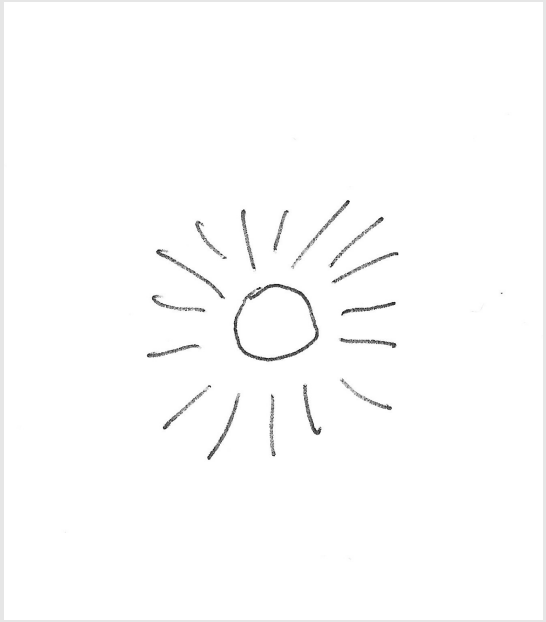


Indoor Residential Fixtures:
surface-mount; area lighting



Streetlights: light levels on ground
LED offers many precisely directed beams

Most Efficient A-Lamps?

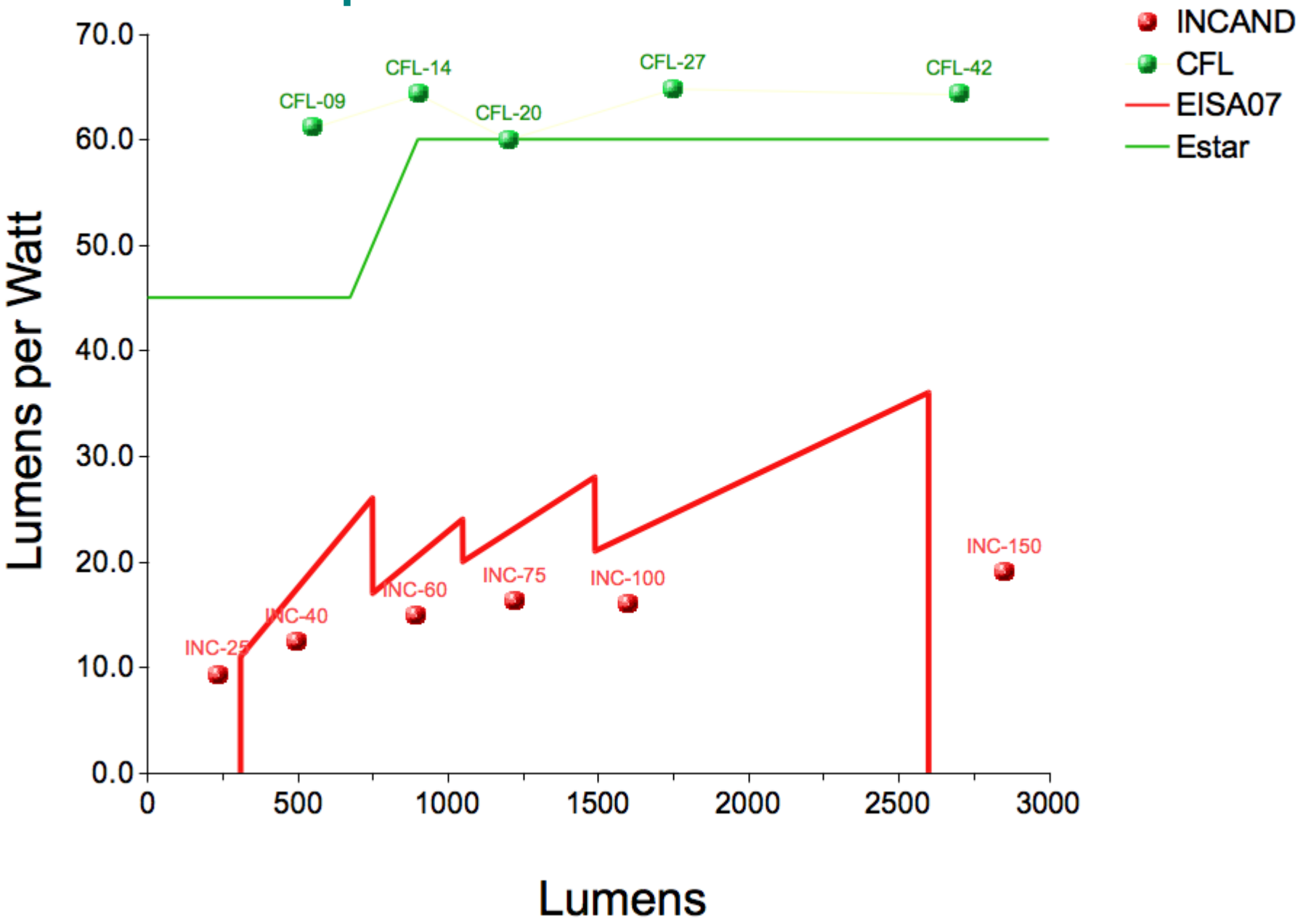


What is the most efficient light bulb?

Which is more efficient: CFL or LED?

"light bulb"
= "general purpose" lamp
= "Edison base / medium-base A-shape"
= "omni-directional" lamp

A-Lamps INC & CFL Circa 2007



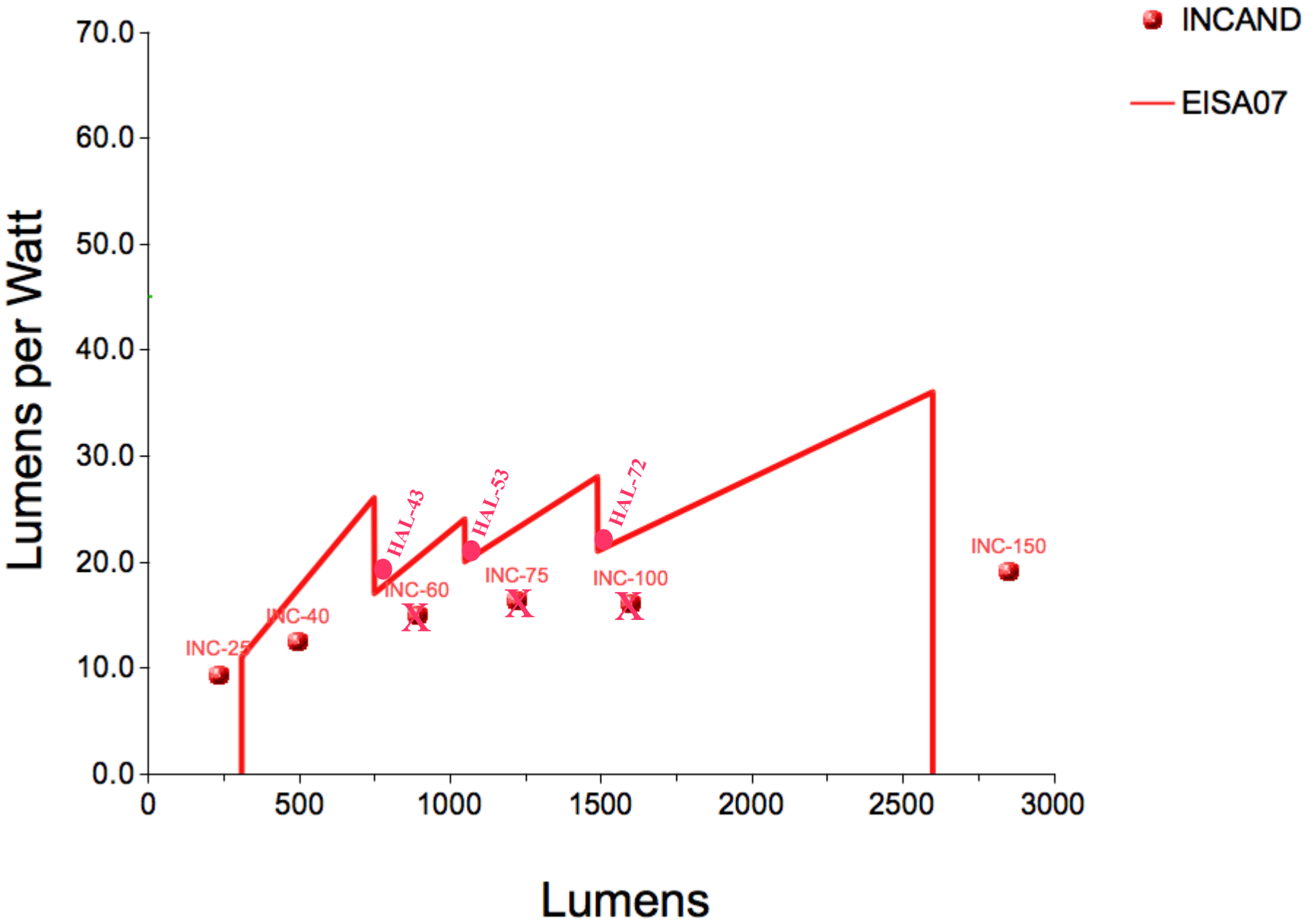
Most Efficient A-Lamps?

Old incand			Best non-halogen		
W	Lm	LPW	Lm	LPW	Gone as of
60	800	13	890	15	2014
75	1100	15	1220	16	2013
100	1600	16	1710	17	2012

Most Efficient A-Lamps?

Old incand			New EISA halogens		
W	Lm	LPW	W	Lm	LPW
60	800	13	43	785	18
75	1100	15	53	1050	20
100	1600	16	72	1490	21

A-Lamps INC Circa 2014



A-Lamps Best CFL 2014

Old incand			Best CFL today		
W	Lm	LPW	W	Lm	LPW
60	800	13	13	925	71
75	1100	15	18	1300	72
100	1600	16	23	1650	72

LED A-Lamps

omni-directional LED: major engineering challenges

Nov 2010: first EnergyStar LED 40W equiv: 8W

LED A-Lamps

	Min Lm	Best CFL			EStar LED		
		W	Lm	LPW	W	Lm	LPW
60	800	13	925	71	13	800	62
75	1100	18	1300	72			
100	1600	23	1650	72			

Jun 2011: first EnergyStar LED 60W equiv

price: ~~$40!~~ Sep 2011: $25!

LED A-Lamps

	Min Lm	Best CFL			Best Estar LED		
		W	Lm	LPW	W	Lm	LPW
60	800	13	925	71	9.8	1008	103
75	1100	18	1300	72			
100	1600	23	1650	72			

DOE awards L Prize! Aug 3, 2011

Energy Star rating May 2012

First LED A-lamp to exceed CFL efficacy

LED A-Lamps

	Min Lm	Best CFL			Best Estar LED			qty Estar
		W	Lm	LPW	W	Lm	LPW	LED models
60	800	13	925	71	9.8	1008	103	7
75	1100	18	1300	72	16	1277	80	1
100	1600	23	1650	72				

As of Oct 2012 LED Energy Star equivalent models:

7 60W equivalents, including 2 exceeding CFLs:

5: 60-70 LPW

1: 79 LPW

1: 103 LPW (L-Prize)

1 75W equivalent

How many models efficiency-worthy? … only three!

LED A-Lamps

	Min Lm	Best CFL			Best Estar LED			qty Estar
		W	Lm	LPW	W	Lm	LPW	LED models
60	800	13	925	71	~~9.8~~	~~1008~~	~~103~~	7
75	1100	18	1300	72	16	1277	80	1
100	1600	23	1650	72				

As of Oct 2012 LED Energy Star equivalent models:

7 60W equivalents, including 2 exceeding CFLs:

5: 60-70 LPW

1: 79 LPW

~~1: 103 LPW~~ (L-Prize) unavailable! as of 2013

1 75W equivalent

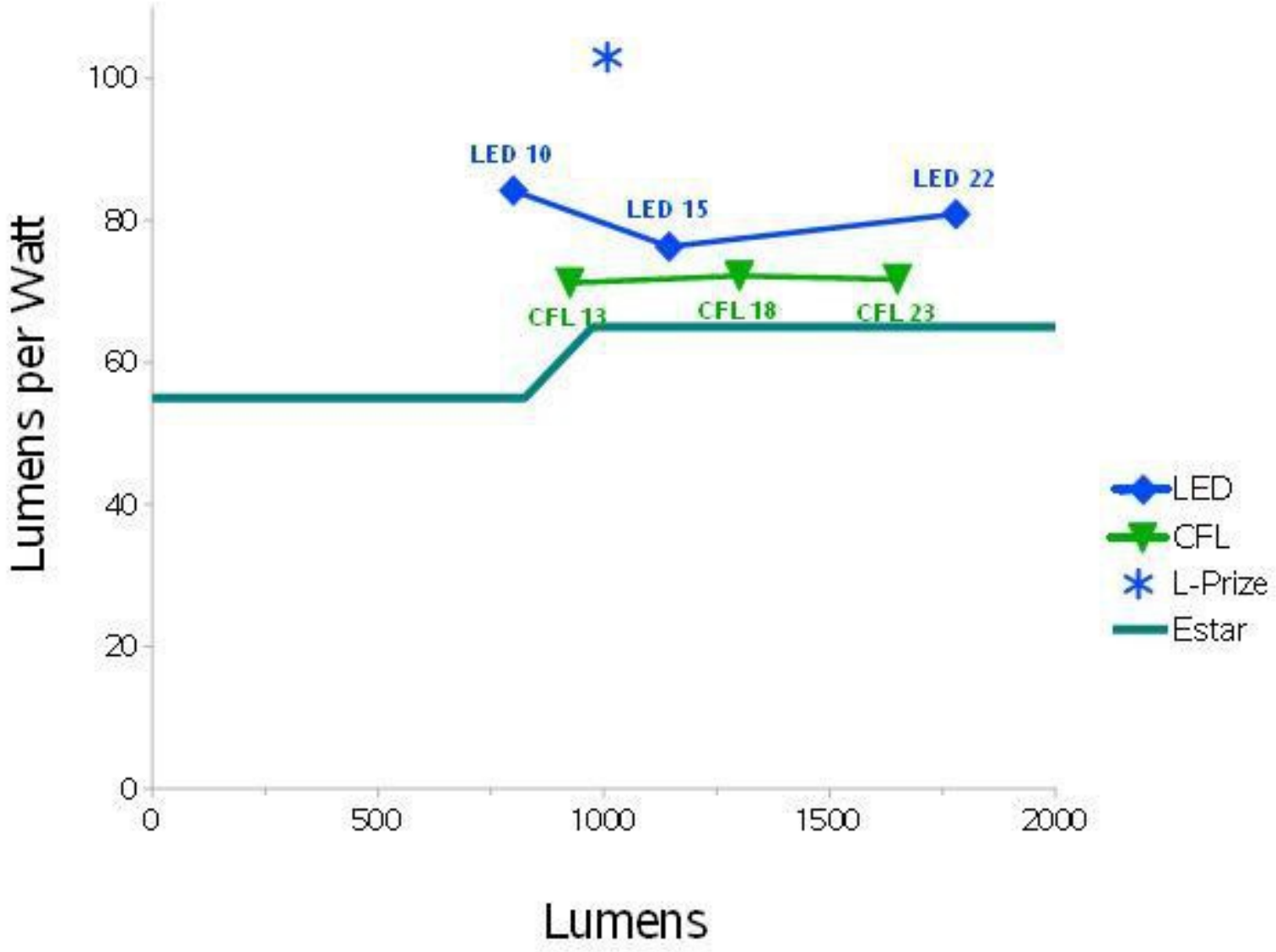
How many models efficiency-worthy? … ~~only three!~~

LED A-Lamps

	Min Lm	Best CFL			Best LED		
		W	Lm	LPW	W	Lm	LPW
60	800	13	925	71	9.5	800	84
75	1100	18	1300	72	15	1180	78
100	1600	23	1650	72	22	1780	81

As of Feb 2014

A-Lamps Best CFL & LED 2014



LED A-Lamps

	Min Lm	Best CFL			Qty Estar LED Models			
		W	Lm	LPW	>70 LPW	<70 LPW	<Estar*	total
60	800	13	925	71	32	55	0	87
75	1100	18	1300	72	5	6	4	11
100	1600	23	1650	72	6	2	1	8
					43	63	5	106

As of Feb 2014

LED A-Lamps

	Min Lm	Best CFL			Qty Estar LED Models			
		W	Lm	LPW	>70 LPW	<70 LPW	<Estar*	total
60	800	13	925	71	32	55	0	87
75	1100	18	1300	72	5	6	4	11
100	1600	23	1650	72	6	2	1	8
					43	63	5	106

As of Feb 2014

How many efficiency-worthy?

LED A-Lamps

	Min Lm	Best CFL			Qty Estar LED Models			
		W	Lm	LPW	>70 LPW	<70 LPW	<Estar*	total
60	800	13	925	71	32	55	0	87
75	1100	18	1300	72	5	6	4	11
100	1600	23	1650	72	6	2	1	8
					43	63	5	106

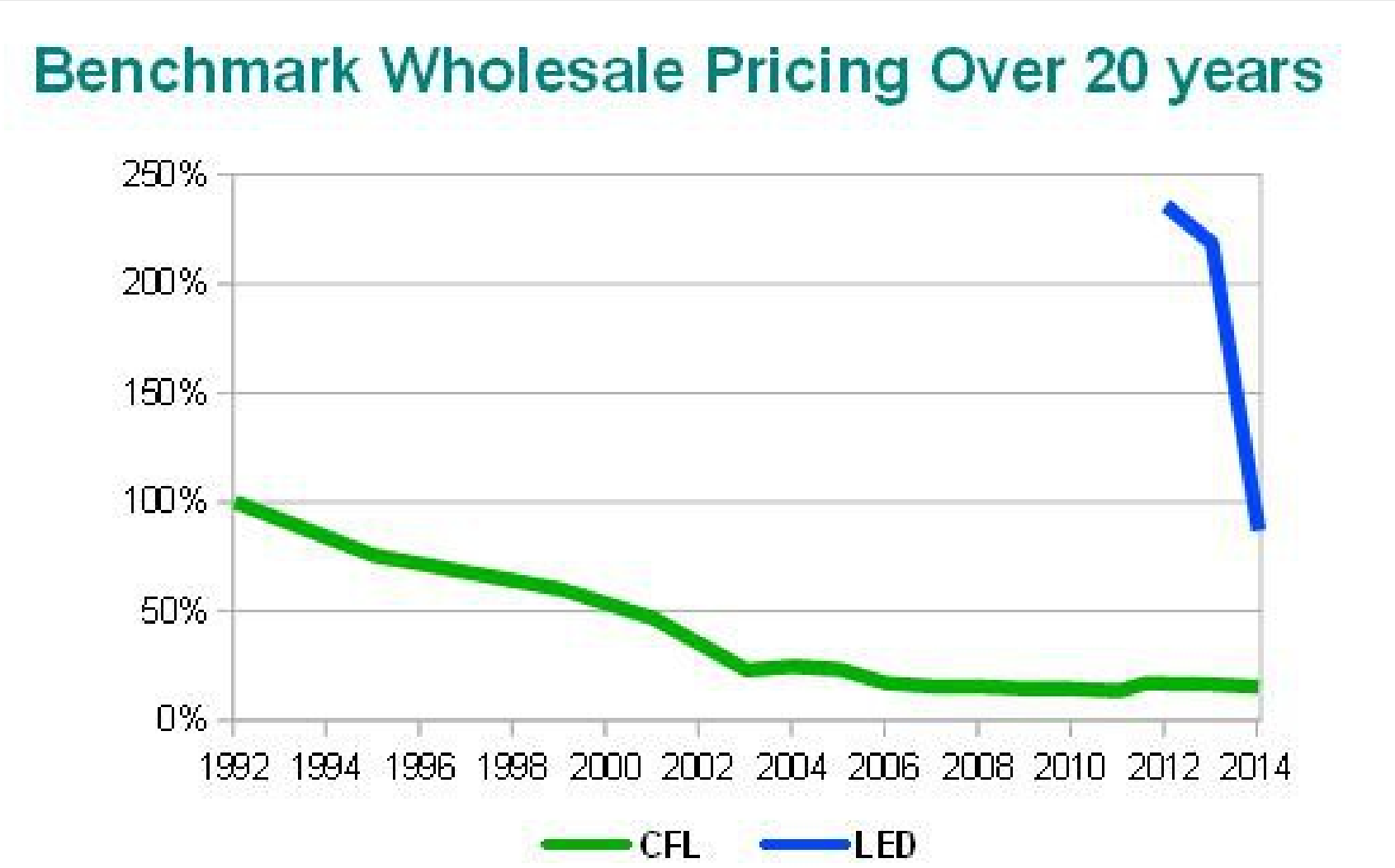
As of Feb 2014

How many efficiency-worthy?

Less than half!!

*will not meet EnergyStar as of Sep., 2014

A-Lamps


Benchmark Wholesale Pricing Over 20 years
250%
200%
150%
100%
50%
0%
1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014
CFL
LED

LED A-Lamps

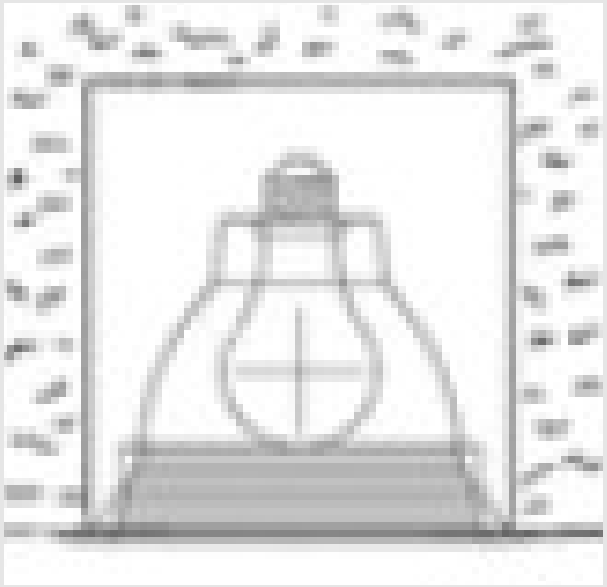
Summary:

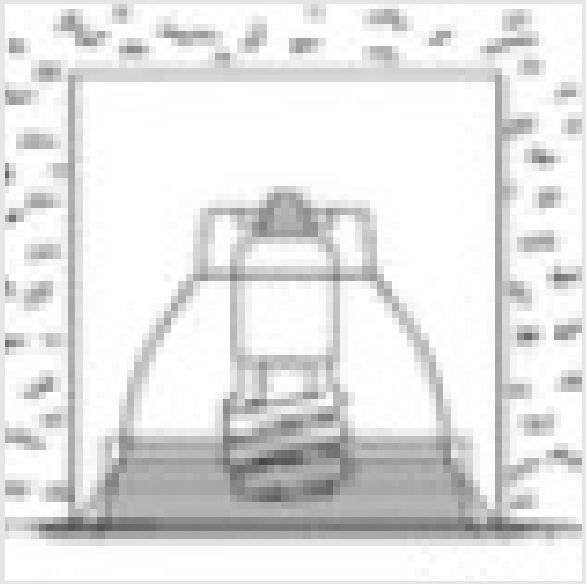
- super bulb >100LPW came and went!
- only incremental improve over CFLs
- mfrs decreasing price, not increasing eff.
- advocacy needed
- only consider Energy Star models
  that significantly exceed efficiency of CFLs
  (warning: fewer than half)
  ~10x cost of CFL

LED A-lamps not a great oppty to decrease energy consumption
consider quality purpose-built LED fixture

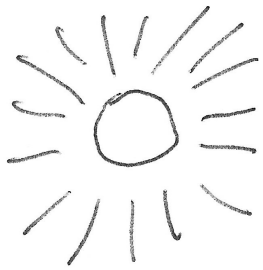
?next-step: “smart” bulbs (=addressable / controllable) … but not necessarily highly-efficient!

LED Downlights

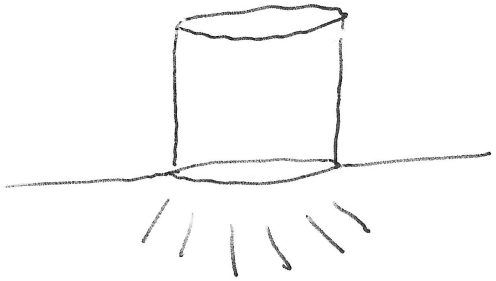




LED Downlights

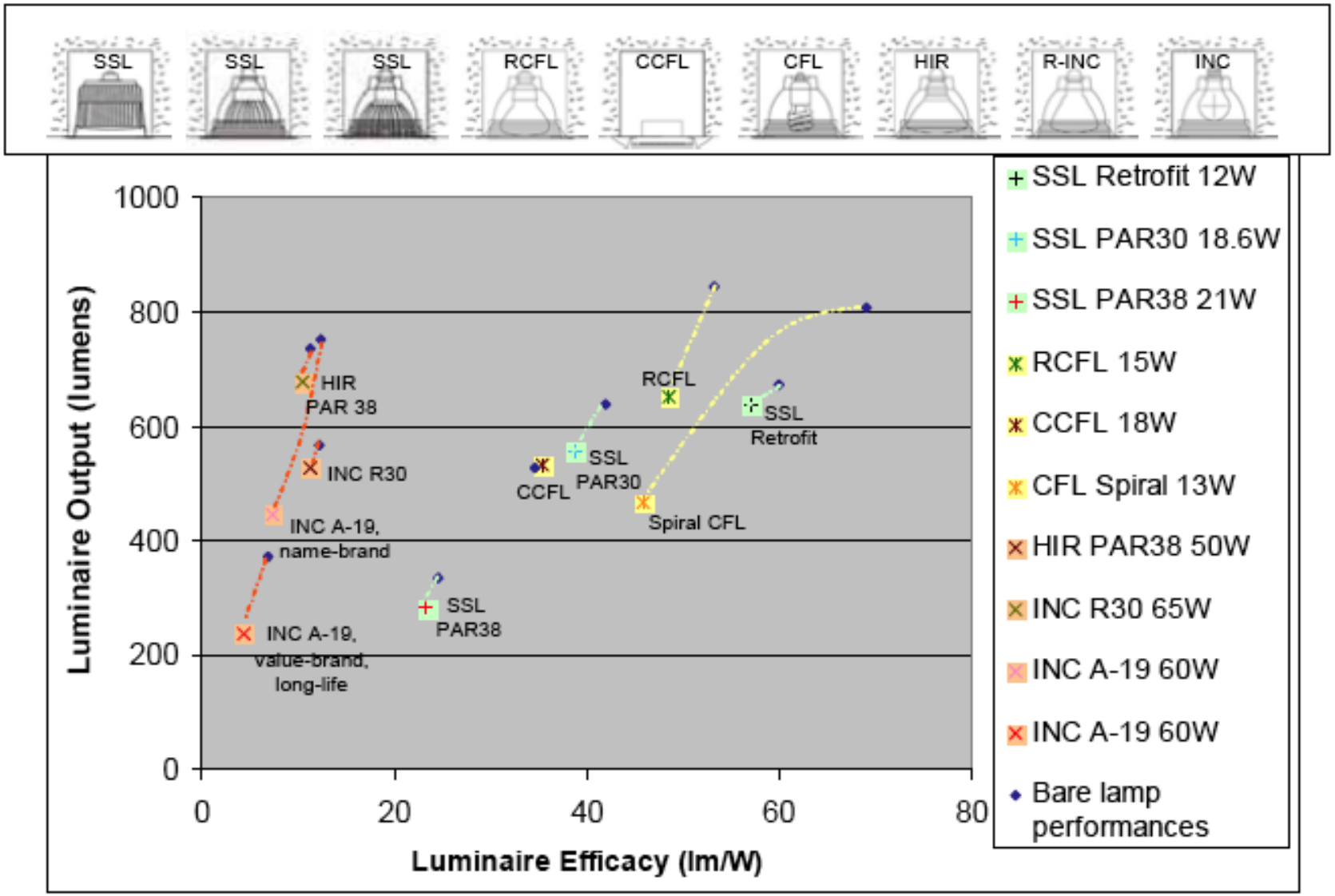


A-Lamps:
omni-directional

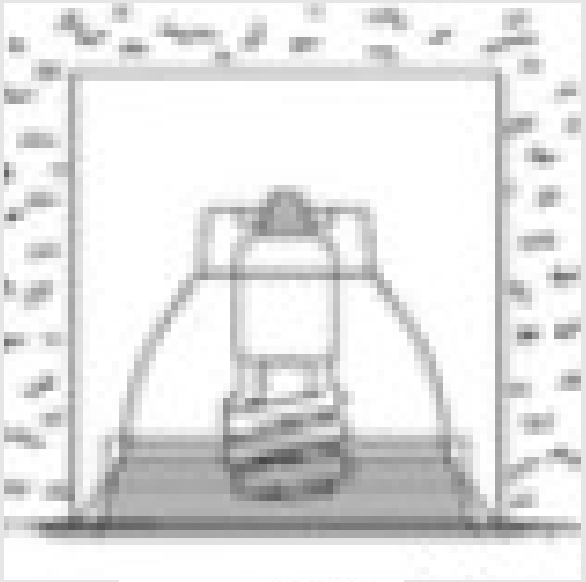


Recessed Can Fixtures:
only directional light is needed

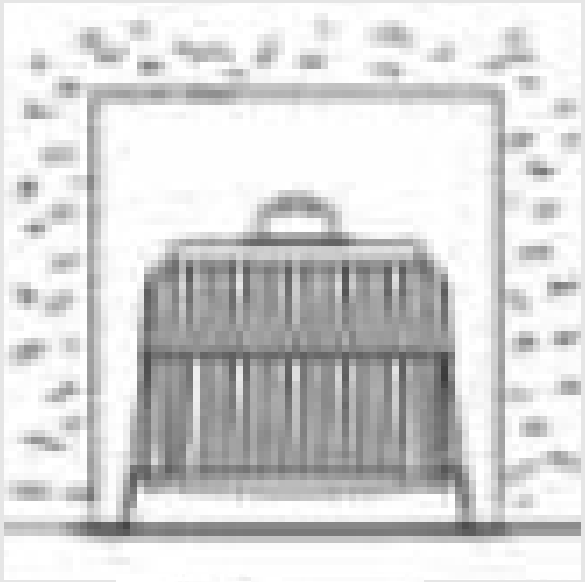
Figure 2. Downlight In Situ Losses. Performance of 6" Recessed Downlight with Different Sources



LED Downlights



CFL
Spiral 13 W
466 lm
46 lm/W



SSL
Retrofit 12 W
639 lm
57 lm/W

LED Downlights

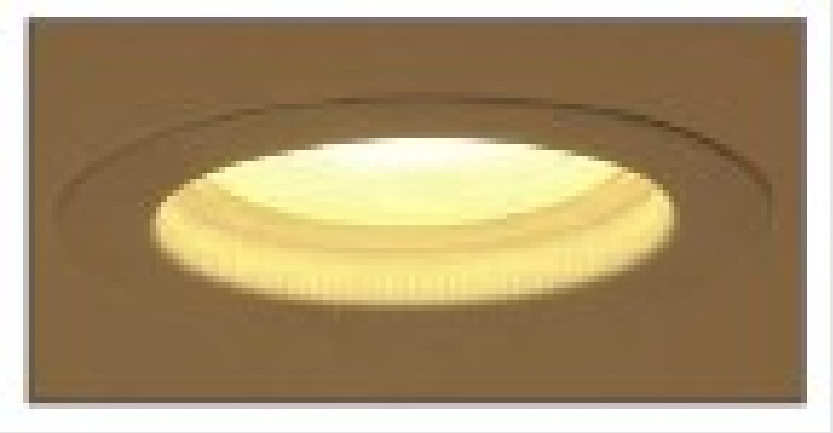
"the first LED ... to start the lighting revolution, combining numerous technical innovations"
parity with CFL was a radical development

Was 12W

Now 10.5W

Fixture efficiency:
62 LPW

LED Downlights

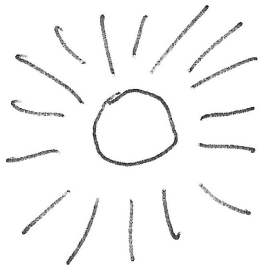


LED Downlights

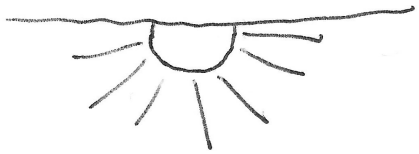
Number of models on EnergyStar QPL	as of Oct 2012	as of Feb 2014
LED Retrofits	288	649
LED New Fixture	568	1172

Efficiencies range from ~90 LPW down to a low of 42!

Indoor Area Fixtures



A-Lamps:
omni-directional



Indoor Residential Fixtures:
surface-mount; area lighting

Indoor Area Fixtures

Efficiency-Worthy LED indoor area fixtures??

Indoor Area Fixtures

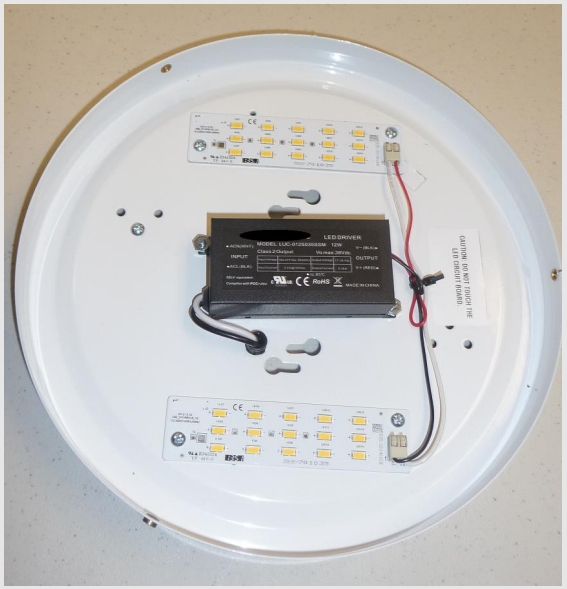
Efficiency-Worthy LED indoor area fixtures??

Until 1 year ago: NO.

There was not any demonstrably energy-advantageous general indoor lighting LED fixture until spring of 2013.

Indoor Area Fixtures

Typical (used)
CFL “pan” fixture
shown w/out
diffuser; 2 13W
twin tubes



Typical (new)
LED “pan” fixture
showing chip
arrays

Indoor Area Fixtures

CFL →

← LED

Indoor Area Fixtures

Energy Star's current residential fixture program (v.1.2)

measures efficiency of light source, not fixture

CFLs:

~ 2000 models of CFL ceiling fixtures Energy Star qualified

top source efficiency: 74 LPW

LEDs:

2013 Jan: first LEDs fixtures listed, did not excel in efficiency

Mar: 71 LED models exceeded CFL efficiencies, many 94-98 LPW

Apr: 115 efficiency-worthy LED models

Aug: 160 efficiency-worthy LED models

2014 Feb: 316 efficiency-worthy LED models

183 LED models > 90 LPW

but also many below 74!

Indoor Area Fixtures

Energy Star's current residential fixture program (v.1.2)
measures efficiency of light source, not fixture

So shouldn't we check on the light output from the fixture?

Requires photometric report.

CFL →

← LED

Indoor Area Fixtures

CFL - 25w Fixture

ZONAL LUMEN SUMMARY

ZONE	LUMENS	% LAMP	% LUMINAIRE
0-30	116.9	6.5%	19.7%
0-40	193.4	10.7%	32.6%
0-60	353.4	19.6%	59.5%
60-90	153.7	8.5%	25.9%
70-100	112.0	6.2%	18.9%
90-120	56.1	3.1%	9.5%
0-90	507.1	28.2%	85.4%
90-180	86.8	4.8%	14.6%
0-180	593.9	33%	100%

LUMENS PER ZONE

ZONE	LUMENS	% TOTAL	ZONE	LUMENS	% TOTAL
0-10	14.1	2.4%	90-100	25.2	4.2%
10-20	40.6	6.8%	100-110	17.9	3%
20-30	62.2	10.5%	110-120	13.0	2.2%
30-40	76.5	12.9%	120-130	9.9	1.7%
40-50	81.9	13.8%	130-140	7.6	1.3%
50-60	78.2	13.2%	140-150	5.7	1%
60-70	67.0	11.3%	150-160	4.2	0.7%
70-80	51.2	8.6%	160-170	2.5	0.4%
80-90	35.6	6.0%	170-180	0.7	0.1%

LED - 12w Fixture

ZONAL LUMEN SUMMARY

ZONE	LUMENS	% LUMINAIRE
0-30	136.4	21.4%
0-40	224.9	35.3%
0-60	407.1	64%
60-90	165.0	25.9%
70-100	113.5	17.8%
90-120	46.7	7.3%
0-90	572.1	89.9%
90-180	64.4	10.1%
0-180	636.5	100%

LUMENS PER ZONE

ZONE	LUMENS	% TOTAL	ZONE	LUMENS	% TOTAL
0-10	16.5	2.6%	90-100	22.8	3.6%
10-20	47.4	7.5%	100-110	14.5	2.3%
20-30	72.5	11.4%	110-120	9.4	1.5%
30-40	88.5	13.9%	120-130	6.4	1%
40-50	93.8	14.7%	130-140	4.5	0.7%
50-60	88.4	13.9%	140-150	3.3	0.5%
60-70	74.3	11.7%	150-160	2.2	0.3%
70-80	54.9	8.6%	160-170	1.1	0.2%
80-90	35.8	5.6%	170-180	0.3	0%

Total lumen output from fixture

594 lumens

637 lumens

Fixture efficiency

= 24 LPW

= 53 LPW

Either can replace 85 - 120 watts of incandescent

Indoor Area Fixtures

CFL →

← LED

In this case:

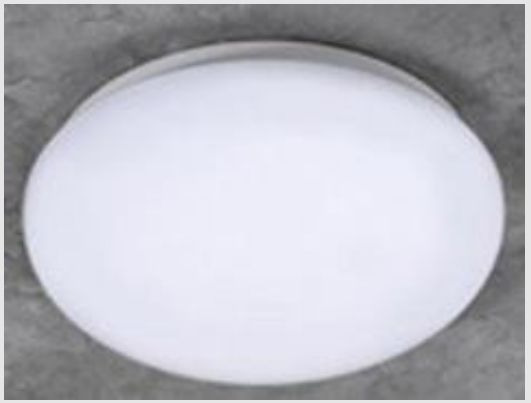
from CFL:

~ 50% savings with LED

from incandescent:

~ 88% savings with LED

Indoor Area Fixtures



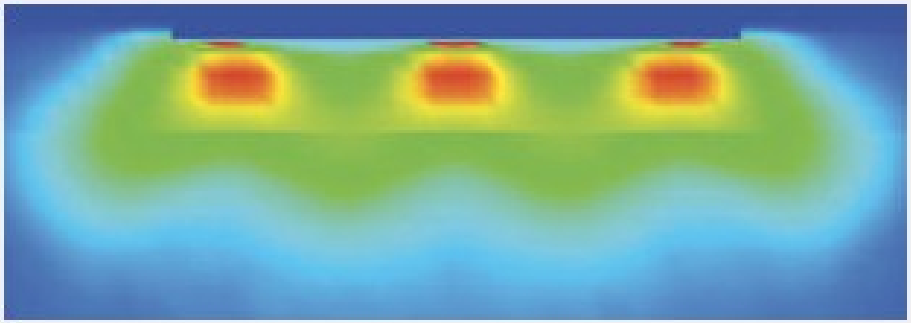
All of these are Energy Star listed. All are 95 LPW source.

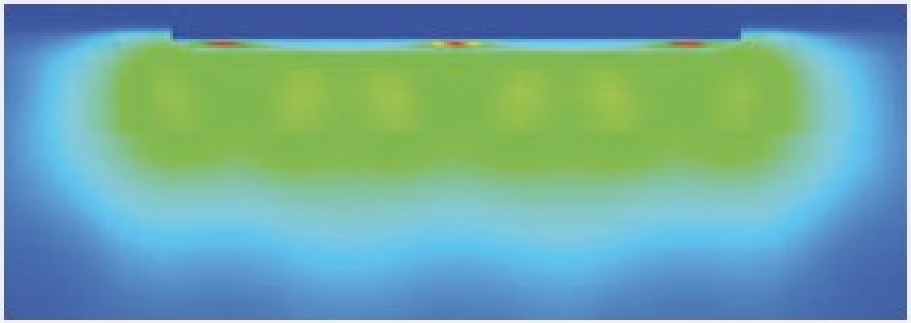
Indoor Area Fixtures

Summary:

- efficiency-worthy LED products available only in last year
- only consider Energy Star
- only consider > 74 LPW source efficiency
- assure that LED fixture performance exceeds CFL
- if all the above, this is GREAT opportunity for residential energy

LED Streetlights

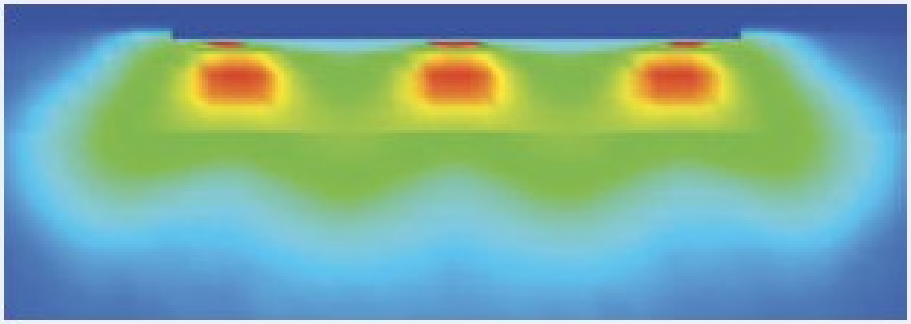


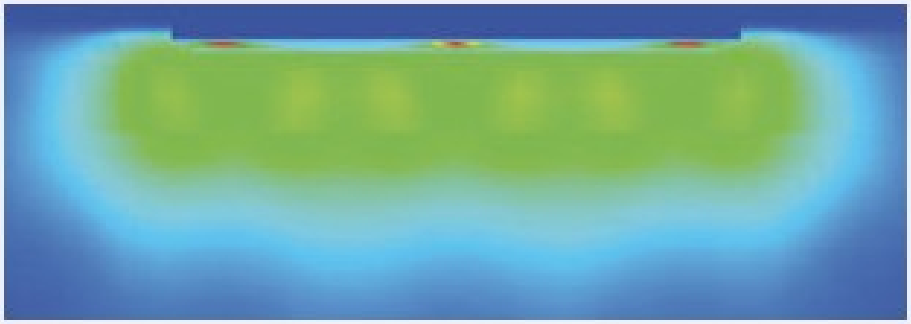


LED Streetlights

HID (current practice)
~56 LPW

LED
~100 LPW



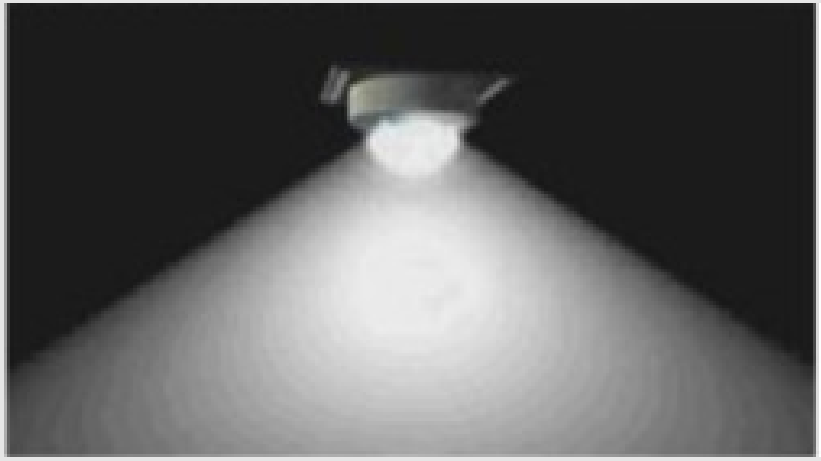


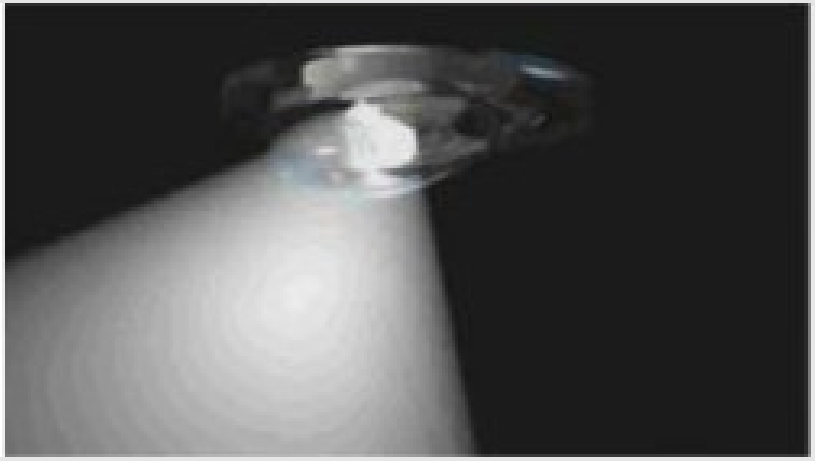
Looking straight down at the ground from above fixtures.

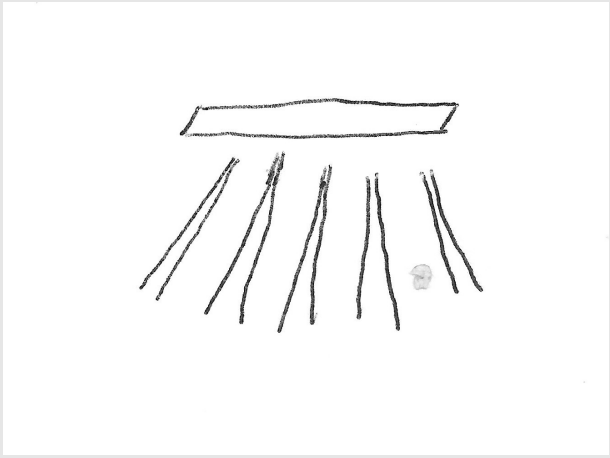
Colors indicate relative light intensity on the ground.

Green = just the right footcandle level

LED Streetlights







LED Streetlights

Institutionally:

Who Pays?

Who Owns?

LED Streetlights

Salute to: George Woodbury, "Mr. Streetlights"

Responsible for first-in-country:

Massachusetts General Law C. 164 s.34A – 1997:
any city or town may purchase their streetlights from the utility companies

Now, a few other states: CT, ME, RI.

Also first in the country, 2012:

Massachusetts State Contract FAC76 Category 6

Massachusetts Operational Services Division
in consultation with the Metropolitan Area Planning Council

provides procurement path for any municipality to purchase LED streetlight fixtures without having separate bid process

LED Streetlights

Case Study presented here for the first time:

Town of Dartmouth, Massachusetts.

Change out HPS roadway streetlights with LED fixtures.

Number of fixtures: 1,658.

Installation completed: November, 2013.

LED Streetlights

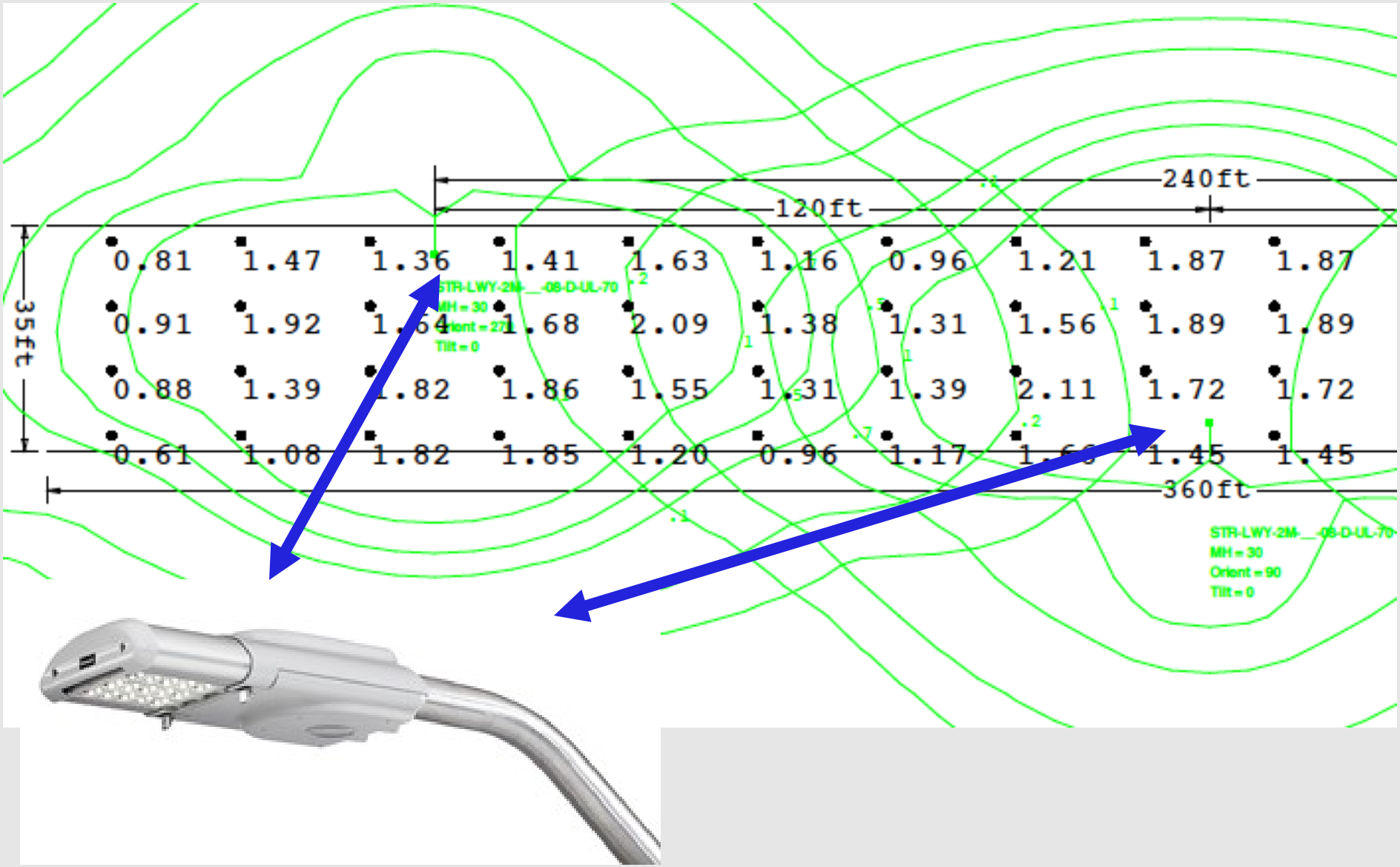
David Cressman
Dartmouth
Town Administrator

PROJECT DETAILS

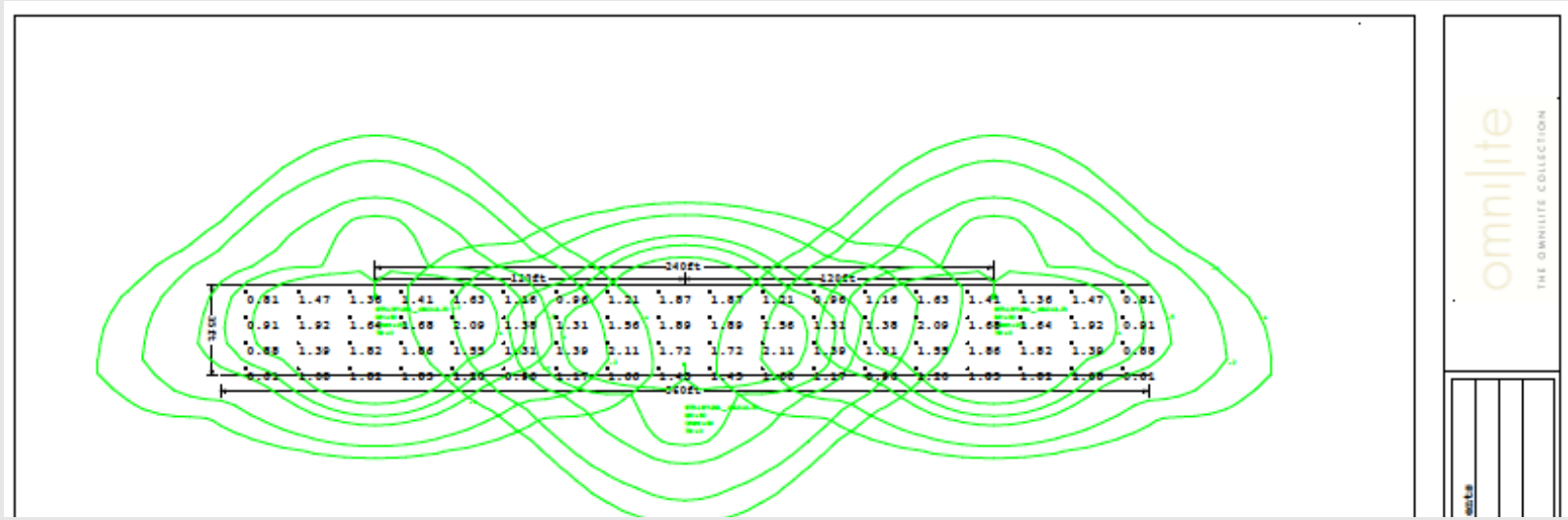
Kilowatt hours reduced annually	418,569
Total Cost	$463,483
NSTAR Incentive	$104,827
Net Municipal Cost	$358,656
Total Annual Savings	$79,600
Simple Payback Period (years)	4.5

68% Energy Savings!

LED Streetlights



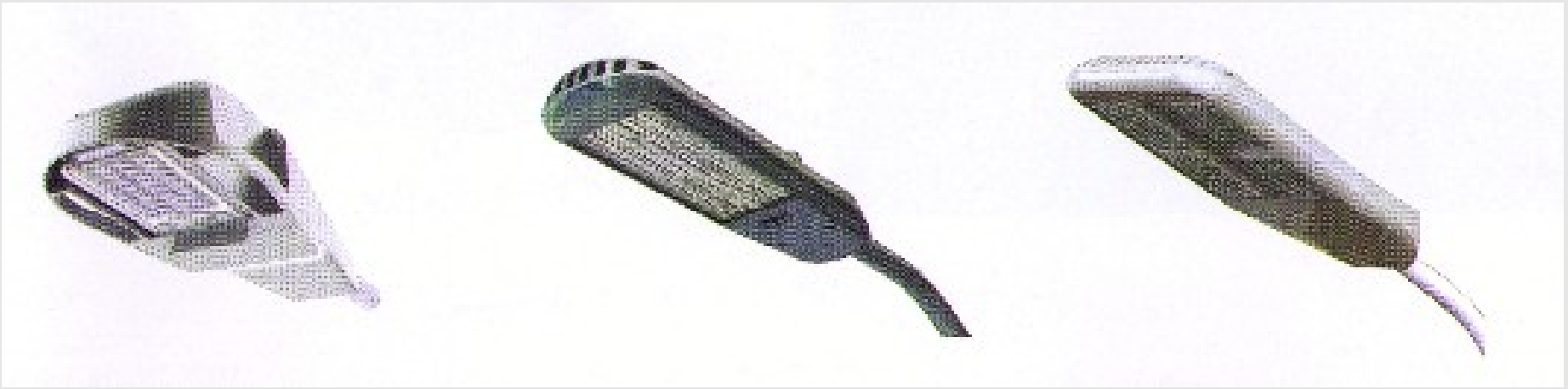
LED Streetlights



Luminaire Schedule						
Symbol	Qty	Label	Arrangement	Lumens	LLF	Description
	3	STR-LWY-2M-__-08-D-UL-70	SINGLE	N.A.	1.000	STR-LWY-2M-08-D-UL-700-43K

Calculation Summary							
Label	CalcType	Units	Avg	Max	Min	Avg/Min	Max/Min
CalcPts	Illuminance	Fc	1.45	2.11	0.61	2.38	3.46

LED Streetlights



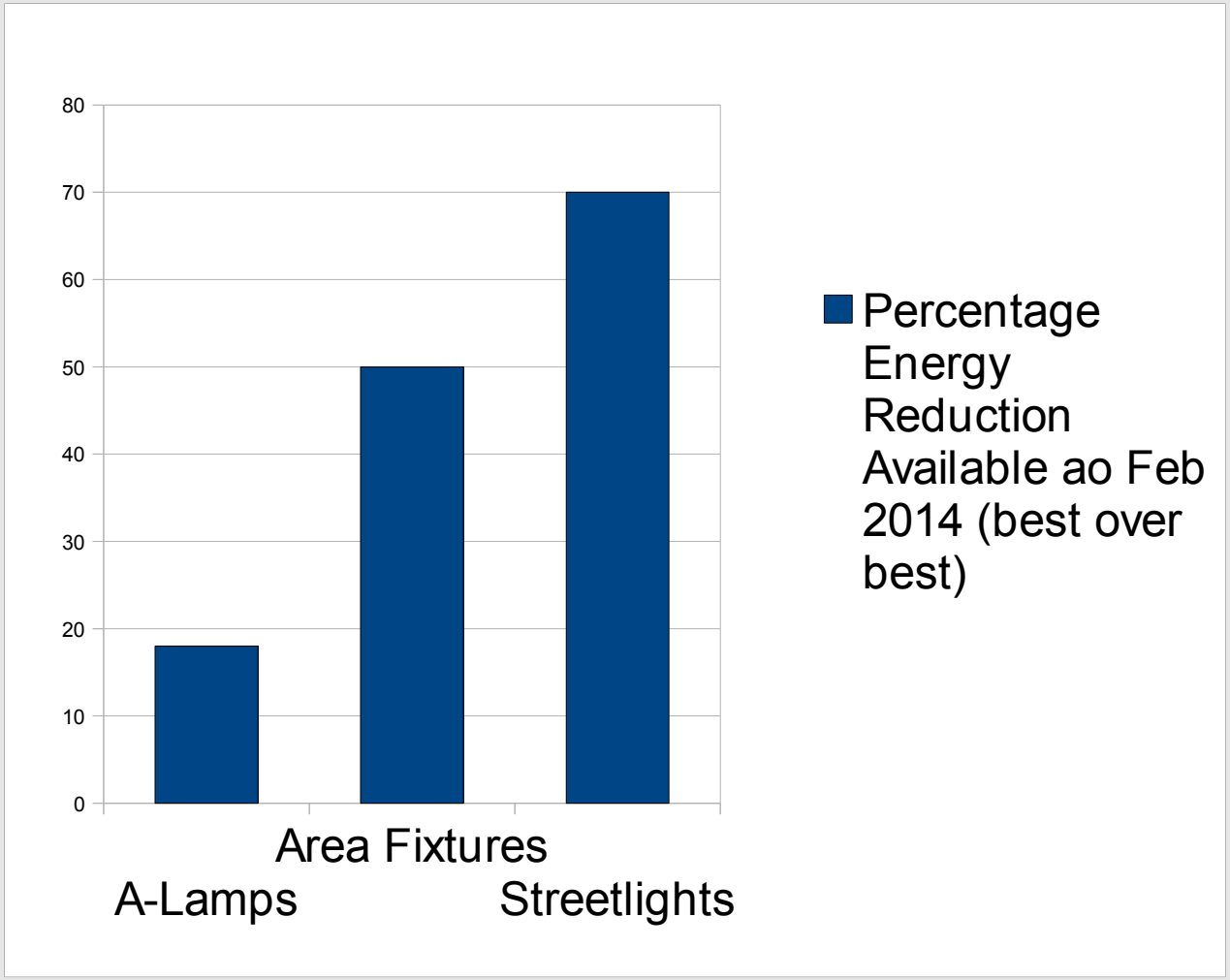
LED Streetlights

Summary:

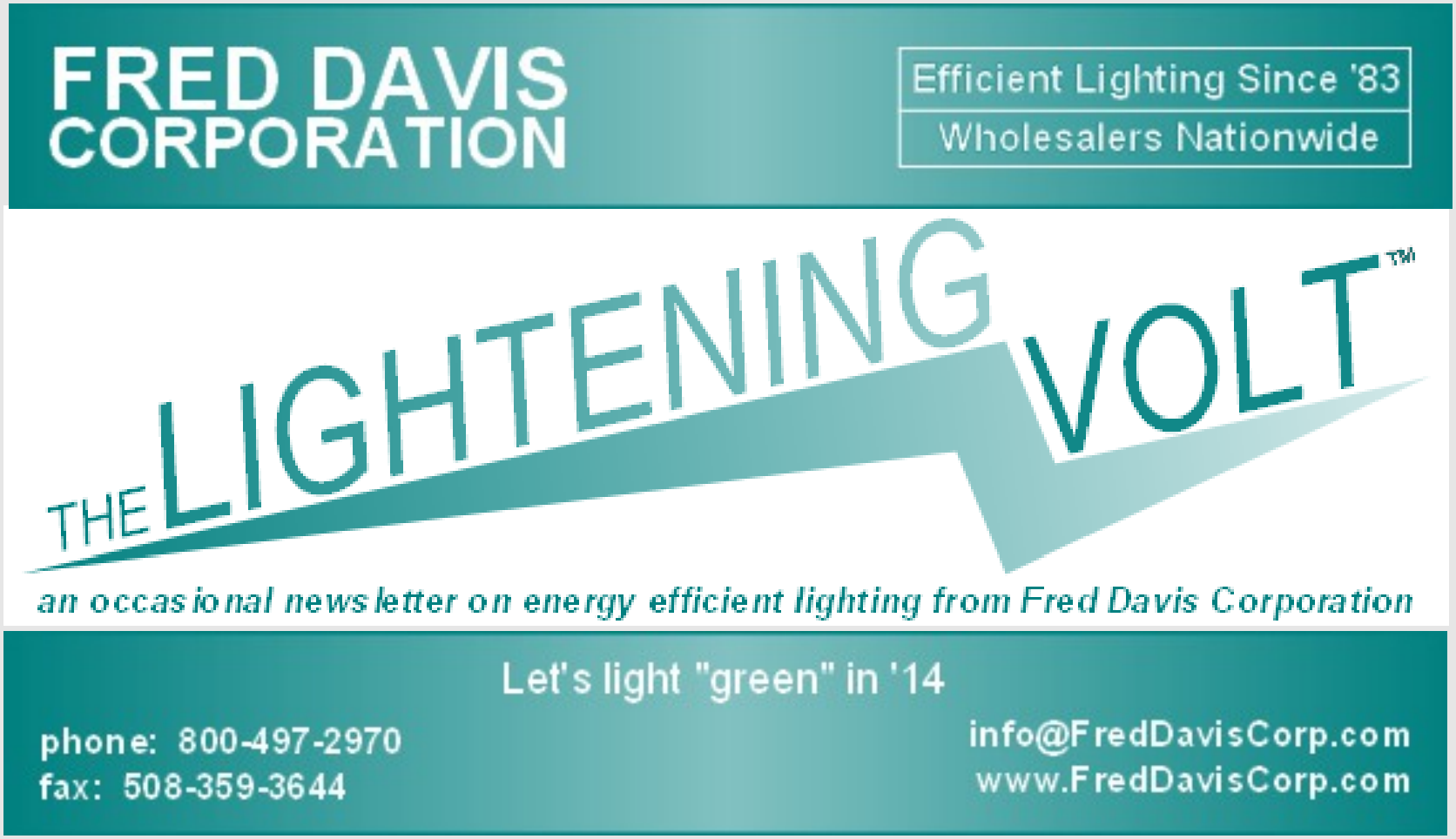
- "first time" for each municipality
- huge (~70%) savings
- now very cost-effective
- be aware – *we'll do that for you* – !

coming?: opportunities for control / communication

LEDs in three Applications



This concludes The American Institute of Architects Continuing Education Systems Program.



Contact us for free e-newsletter on developments in efficient lighting